Art. XIII.—*The Age of the Metamorphic Rocks of North-Eastern Victoria.*

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[With Plates XIX.–XXI.].

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I.—Introduction.

The geological history of Victoria is generally represented as beginning in the ordovician (lower silurian) period.[1] This view is based upon the belief that the broad areas of schists and metamorphic rocks in the extreme west, and in the north-east of Victoria have been formed by the metamorphism of silurian and ordovician rocks in post-silurian times. This view is repeatedly expressed in the geological literature of Victoria. Dr. Selwyn attributes such an origin not only to the schists, but even to the granites. He stated[2] that the "granites are in no sense intrusive or irruptive masses, but only the completely-transmuted ends of the silurian rocks that have either been lowered in early geological times to within the influence of central heat, or by some means been subjected to other powerful transmuting agencies."[3]

The same theory is taught in Mr. R. A. F. Murray's "Physical Geography and Geology of Victoria" (pp. 37, 38); and Mr. A. W. Howitt lent the weight of his authority to this view by maintaining the existence of a passage from silurian sediments to metamorphic rocks in various parts of the Victorian Alps. In Mr. Howitt's later papers this view was re-considered in so far that the felspathic metamorphic rocks were regarded as altered plutonic rocks, and only the non-felspathic schists as altered

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1 Exclusive of a small band near Heathcote, that has been described as cambrian.

2 Spec. Rep. Geol. Surv. Vict., 1892.

3 A. R. C. Selwyn: Notes on the Physical Geography, Geology and Mineralogy of Victoria. Internat. Exhib. Essays, 1866-1867, p. 155, Official Record, Melbourne, 1866.

sedimentary deposits. The most weighty expression of this view is given in Mr. Howitt's memoir, "Notes on the Contact of the Metamorphic and Sedimentary Formation at the Upper Dargo River,"[1] which is based upon careful study of a series of microscopic examinations of the rocks in question. Mr. Howitt there pointed out that the metamorphic rocks are of two distinct origins. The first set includes a series of schists containing felspar; Mr. Howitt no doubt quite correctly regards them as metamorphosed examples of igneous rocks. In regard to the second group, he concludes[2] that "when the crystalline schists are simply mica schists, without traces of felspar, and are connected by gradations with the sedimentary formations, they are clearly metamorphosed representatives of the latter."

Mr. Howitt explained that "the sediments are metamorphosed into mica schists, the plutonic rocks into mica schists and gneisses, and there is thus created an appearance of gradual transition from the normal sediments to the normal massive plutonic rocks."[3]

This view was a great advance on the theory of the origin of gneisses and granite by the alteration of lower Palaeozoic slates and sandstones; but it still accepted the view of the Ordovician and Silurian age of the materials in the metamorphic series.

Dr. Selwyn's theory is expressed in the Geological Survey map of Victoria, the preparation of which was concluded last year, and which has recently been issued. The explanation of the map describes the metamorphic rocks as containing "metamorphosed lower Silurian rocks east of Beechworth and at Stawell, silky micaceous schists, mica schists, and gneiss of many varieties, passing from unaltered Silurian into metamorphic granite."

Anxious to get a definite base for the geological history of Victoria, I had taken the first opportunity for a visit to the north-eastern district to examine the relations of the metamorphic and the normal palaeozoic rocks. The weather was unfavourable, and, though I found the two sets of rocks in close juxtaposition on the Cobungra Creek, a heavy snow fall covered them before I found the line of junction. I saw sufficient, however, to make me doubt the asserted passage from the silurian to the metamorphic

1 Spec. Rep. Geol. Surv., Vict., 1892.

2 *Op. cit.*, p. 8.

3 *Ibid.*, p. 9.

rocks. A second search near Omeo was rendered futile by the fact that the boundary between the schists and sediments was not where it was marked on the then current edition (1880) of the Geological Survey map, on the scale of 8 inches to the mile. I accordingly failed to find the junction until too late to use it. That mattered the less, as Mr. A. W. Howitt had already determined that the schists in that case were not altered palaeozoic sediments, but altered plutonic rocks.

In my second vacation I returned to the north-east to renew this search on the boundary of the metamorphic rocks in Bogong. Snow and fog again hid the junction on the main divide, so I turned northwards to Yackandandah, hoping to find satisfactory exposures at a lower altitude.

II.—The Metamorphic and Ordovician Rocks at Yackandandah.

The Geological Survey map of Victoria shows the ordovician and metamorphic rocks at Yackandandah in close contact along Commissioner's Creek and crossing the ridge which separates that valley from Indigo Creek. The saddle between the heads of the two creeks looked a hopeful place at which to find exposures of the two series of rocks showing their mutual relations.

Yackandandah is situated on some flats beside the Yackandandah Creek, near its junction with Commissioner's Creek and Nine Mile Creek (Pl. XIX.). To the east is a low track of biotite-plagioclase-granite and granodiorite. To the north-west the rocks are all metamorphic, and they end westward along a line running from south-east to north-west against the ordovician rocks with granitic intrusions. Commissioner's Creek is shown on the map as flowing from the north-west, along the junction between the metamorphic and ordovician series. Nine Mile Creek flows from the south-west, apparently at right angles to the strike of the ordovicians.

The only literature upon this precise locality to which reference need be made is a paper by Mr. A. W. Howitt, "Notes on the Geology of the Ovens District, with Remarks on the Deep Leads." This paper includes[1] a brief account of Twist Creek, and

[1] Prog. Rep. Geol. Surv., Victoria, II., p. 78, 1874.

an admirable illustration of the contorted character of the gneiss and schist of Commissioner's Creek.

My first excursion from Yackandandah was along Commissioner's Creek in order to get a general idea of the creek and the rocks on both sides. The schists are exposed in the first cutting on the road along Commissioner's Creek. They strike to the north, and stand nearly vertical. They are traversed by euritic dykes, of which the largest is two feet in width. The next road cutting shows weathered mica schists, with small quartz veins. After crossing a small brook, and just before reaching another road cutting, a track leads to the left, by a watercourse passing near an old roofless wooden house. The track leads to a quarry, at the foot of the steep ridge. The rocks here are as metamorphic as those on the eastern side of the valley. The strike is from N.N.W. to S.S.E., and the main rock is a fine grained black gneiss, cut through by some dykes. Search for the junction with the ordovician series had, therefore, to be made further to the south-west. The ridge which is marked on the map as rising to 867 feet, is composed mainly of a medium grained gneiss and dykes of red pegmatite. On the ridge is some coarser hornblendic gneiss, the strike of which is generally to the north-west parallel to Commissioner's Creek. On the south-western side of this ridge lies Wood Cutter's or Sawpit Gully, the rocks on the left bank of which are mainly schists and gneiss. At the junction of Wood Cutter's or Sawpit Gully and Twist Creek there are some excellent exposures on the bed of the valley, where the gravel has been sluiced away during some mining operations. On the bed of the stream and on the right bank are some good exposures of contorted gneiss and schists, striking north-west by north. A very coarse-grained pegmatite cuts through this series. A little way up Twist Creek from the junction of Sawpit Gully are some beds of slate and sandstone, with a strike of from N.N.W. to N.N.W. by N., and dipping 80 degs. to the west. In the best exposure the beds are vertical, and the strike is N.N.W. $\frac{1}{2}$ N. In the angle between Sawpit Gully and Twist Creek is a wooded spur, from which the only specimens obtained were faulted quartzite and iron-stained micaceous slate. Ascending Twist Creek a series of green sandstones with quartz veins, slates, quartzites, and chloritic slates are seen on the bed of the stream.

These rocks are well exposed within 200 yards of the outcrops of the schists, which there strike N.W. $\frac{1}{2}$ N. Further down the main valley, by a small cataract, there are some well-exposed schists, again striking N.W. $\frac{1}{2}$ N.

I could find in the field no evidence whatever of a passage from the slates into the gneiss and schist series, and the strike of the two sets of beds was different. I have, therefore, examined a set of sections of the rocks in order to see if they show any indication of the derivation of the schists from the ordovician sediments.

III.—The Microscopic Structure of the Rocks.

Beginning with the metamorphic series, a rock from the summit of the ridge between Commissioner's Creek and Sawpit Gully may be taken as a typical example. The rock [154][1] examined microscopically consists of alternate bands of quartz and felspar, about 2 mm. and 3 mm. thick, respectively. At more distant and irregular intervals are dark thin lines. When the rock is examined microscopically the quartz appears in bands composed of mosaic. The felspathic material has been broken up into a complex mosaic of fine-grained constituents. Most of the felspar consist of allotriomorphic grains of plagioclase, which are crowded with granules and small prismatic crystals; both granules and prisms are of the same general character, and both are highly refractive. The small prismatic crystals are recognisable as zoisite, and the granules are probably of the same material. No orthoclase is determinable. With the zoisite are numerous small flakes of white mica. The dark bands lying scattered through the rock are composed of lines of biotite; at intervals the lines are thickened by small segregations of biotite, with which occur some flakes of muscovite. Muscovite is scattered abundantly through the felspathic material, and often occurs along the bands of quartz. The rock has the characters of a gneiss, in which the felspar has been broken up into a mosaic of plagioclase, zoisite and white mica.

Near the junction between the normal metamorphic series and the sediments, both are greatly crushed. On the bed of Twist

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1 The numbers are those of the rock collection of the Melbourne University.

Creek, near its junction with Sawpit Gully, are some hummocks of contorted gneiss. The rock [57; Pl. XX., Fig. 1] examined microscopically is shown to be highly contorted and traversed by a series of small faults; some bands in the rock are dark, owing to the abundance of biotite, and they are separated by layers of white quartz mosaic.

Another type of the metamorphic rocks is represented at the head of Twist Creek by some bands of contorted mica schists. The rock [61] consists of alternations of quartz mosaic and of greenish-white layers, which are intensely contorted, folded and faulted; the whitish layers are composed of packed crystals of white mica with some indeterminable argillaceous material. The rock originally contained many large simple grains of quartz; but the metamorphic action has altered most of them into secondary mosaic. This change, in some cases, has only affected the margin of the quartz grains.

The dykes in the metamorphic rocks are mostly coarse pegmatites. A specimen [65] collected half way up the hill above the stone quarry on the right bank of Commissioner's Creek, is composed of large coarse grains of quartz, intergrown with crystals of comparatively fresh orthoclase. There are some old felspar grains and abundant muscovite. The pegmatite is traversing a fine schist of quartz and muscovite. A second dyke [63] is of much coarser grain; it consists of quartz, muscovite and orthoclase, and contains abundant needles of tourmaline.

The rock of the ordovician series in closest contact with the gneiss is a dark reddish-brown indurated slate [55] with lenticular bands of quartz. Most of the quartz occurs as a fine mosaic, in which larger grains under polarized light show strain effects. The bulk of the rock is a brown crumpled slate, iron stained along lines which are roughly parallel. The constituents of the base are small quartz grains in a cleaved argillaceous base, containing minute crystals of authigenous mica. They appear to have been developed owing to the re-arrangement of the argillaceous material of the ordovician series. A less altered member occurs at the junction between Sawpit Gully and Twist Creek. It [62] is a crushed quartzose grit. Some of the quartz grains have obviously been crushed *in situ*, and there is one thin band of quartz mosaic. There are numerous flakes of muscovite which are crumpled and are clearly allothigenous. The slide includes one thick layer of iron stained argillaceous material, in which the quartz grains are small and scarce. The clastic origin of most of the material is apparent.

In the spur at the western side of Twist Creek occurs a coarse grit [56 ; Pl. XX., Fig. 2] with large quartz grains, nearly all of which are rounded. There are also some rounded grains of hornblende. The interspaces between the quartz grains are occupied by a fine grained quartz mosaic, due to secondary crystallization. Owing to the crushing of the rock, the quartz grains have crushed and caused a certain flow in the softer material. The rock can, therefore, be described as a mylonitic quartz grit. Another variety of arenaceous sedimentary rock occurs a little up Twist Creek, beyond the spur from which the last specimen was obtained. This rock [54; Pl. XXI., Fig. 4] is a fine-grained grit; it is composed of quartz, plagioclase and muscovite. The grains are irregularly arranged; the material is all allothigenous; and the rock represents a slightly altered sandstone, of which the materials were derived from some igneous rocks. A similar rock [58 ; Pl. XXI., Fig. 3] from the bed of Twist Creek, near the junction of the ordovician with the metamorphic series, shows the same materials ; it is a coarser grit in which the fragments are often irregularly oblong, and they are surrounded by fine material in curved lines. The material is stained brown by iron oxide. Between these grains are lines of quartz mosaic, and some of the larger quartz grains are beginning to show alteration into mosaic; but this structure is only developed on the edges or along lines running through the grains.

In the bed of Twist Creek, near the junction with Nine Mile Creek, is a rock [64] showing a further stage in the development of the quartz mosaic. Examined under singly polarized light the rock appears to consist of bands of white structureless material, separated by layers composed of colourless rounded grains, strongly set in a base of pale green slightly pleochroic material. On further examination the green material is shown to be mostly chlorite; the rounded grains in it are quartz and plagioclase, and the white bands break up into quartz mosaic, no doubt due to secondary change, as the large quartz grains are also passing into mosaic.

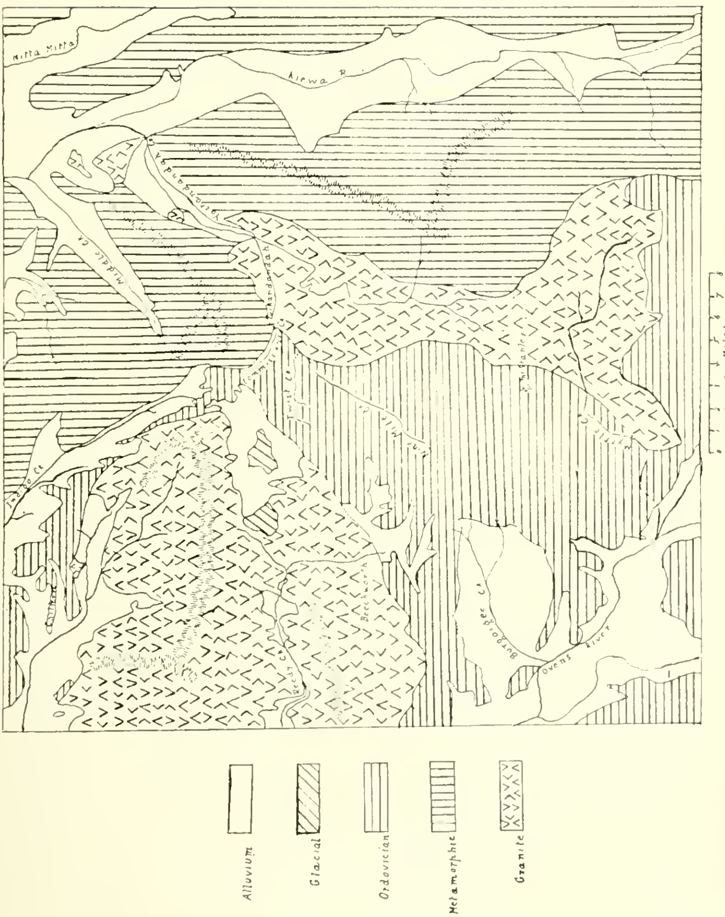
IV.—Summary of Conclusions.

The evidence of the microscopic structure of the rocks and their relations in the field both point to the following conclusions:—First, there is no evidence of a gradual passage from the ordovician to the schists and gneisses. The two rocks have a fairly sharp junction, and their strike is not parallel. Both rocks have been greatly disturbed since ordovician times, so that they have been crushed together, and a clear section showing an unconformable junction between them cannot be expected.

The ordovician rocks appear to be decidedly younger than the schists, for not only are they less altered, but they are clearly clastic rocks, and they appear to have derived most of their materials from pre-existing igneous rocks; they might easily have been formed as a series of shore deposits, derived from the weathering of the adjacent schists.

That the ordovician rocks are a later series than the schists is rendered further probable by their general distribution in the district, as represented by the Geological Survey map. The granitic rocks of Yackandandah have cut through both series, while those at Beechworth are intrusive only into the ordovician rocks. Had the metamorphic rocks been produced by the alteration of the ordovicians we should have expected the rocks close to the great plutonic intrusions to have been the most changed; but on the contrary the metamorphic rocks that extend from Indigo Creek to Wodonga are separated from the granites of the Pilot Range by a narrow band mapped as unaltered ordovician. I have not verified the existence of this band, but the mapping and the theory expressed in the legend of the map are clearly inconsistent. A further objection to the view so long officially accepted is that the distribution of the metamorphic rocks of the Beechworth district does not bear any relation to the granitic instrusions as we might expect had the metamorphic rocks been formed from the ordovicians.

We may therefore conclude that the schist series is a pre-ordovician series, on which the ordovician and silurian rocks have been laid down unconformably. The schist series may be of Cambrian age in the absence of evidence to the contrary, but considering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Yackandandah
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Ovens River
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Alluvium
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Metamorphic
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